

Assessment of fodder quality of leaves of multipurpose trees in sub-tropical humid climate of India

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Abstract: The leaves of 12 species (*Acacia auriculiformis*, *Albizia procera*, *Dalbergia sissoo*, *Gliricidia maculata*, *Leucaena leucocephala*, *Samanea saman*, *Azadirachta indica*, *Eucalyptus hybrida*, *Gmelina arborea*, *Michelia champaca*, *Morus alba*, and *Tectona grandis*) of Multipurpose trees and shrubs (MPTs) grown in the agroforestry arboretum were evaluated for their nutritional characteristics in terms of proximate composition, cell wall constituents, total tannins, major (Ca and P) and trace minerals (Fe, Cu, Zn, Mn and Co), in vitro dry matter and organic matter digestibility (IVDMD and IVOMD) and metabolisable energy (ME) values. There were significant ($P<0.01$) variations among MPTs for all parameters studied. The average values of $(92.02\pm0.30)\%$, $(16.00\pm0.74)\%$, $(3.05\pm0.13)\%$, $(18.97\pm1.07)\%$, $(54.00\pm1.12)\%$ and $(7.98\pm0.30)\%$ (DM basis) were observed for OM (organic matter), CP (crude protein), EE (ether extract), CF (crude fibre), NFE (nitrogen-free extract) and total ash, respectively. Leguminous trees had high CP compared to non-leguminous ones (18.30% vs 13.70%). The mean values for cell wall constituents viz., NDF (neutral detergent fibre), ADF (acid detergent fibre), hemi cellulose, cellulose and ADL (acid detergent lignin) were found to be $(52.48\pm1.05)\%$, $(31.72\pm0.97)\%$, $(20.76\pm0.88)\%$, $(16.97\pm0.70)\%$ and $(9.57\pm0.62)\%$, respectively. The total tannin contents averaged $(4.22\pm0.32)\%$. The ratio of Ca to P was quite wider. The levels of Fe and Mn were adequate to rich in all the MPTs while many of the tree species possessed P, Cu, Zn and Co level below the critical limits for the animals. The average IVDMD and IVOMD values were found to be $(48.96\pm1.30)\%$ and $(50.69\pm1.36)\%$, respectively. The ME value averaged (6.95 ± 0.11) MJ·kg⁻¹ DM. The CP content had significant positive correlation with IVDMD, IVOMD and ME values while NDF, ADF, ADL and total tannins showed negative correlations with these three parameters. Based on the results, *Leucaena Leucocephala* could be considered as good quality fodder as it had the highest level of IVDMD/IVOMD ($65.20\%/67.66\%$) and ME (7.95 MJ·kg⁻¹ DM) while *G. maculata*, *M. alba*, *A. indica*, *D. sissoo* and *S. saman* were of medium type and rest of poor quality.

Keywords: agroforestry; cell wall composition; fodder quality; in vitro digestibility; proximate composition; macro and trace minerals; total tannins; metabolisable energy; multipurpose tree species

Introduction

Multipurpose trees and shrubs (MPTs) play a vital role in agroforestry systems and have a good potential in raising the ruminants' productivity by lessening the gap between demand and supply of fodders, the deficit of feeds being the main constraint in most parts of the world. Also, it is pertinent to evaluate them for various nutritional characteristics so that balanced rations could be formed.

India has the largest livestock population in the world numbering 500 million which constitute about 15% of the global total. The contribution of livestock sector to the gross domestic prod-

uct in India has increased from 4.82% to 5.37% in recent times. In the overall agricultural economy of the country, the livestock sector contributes about 25% to the overall agricultural GDP. In spite of large indigenous stock of cattle population (87%), India leads the world in milk production (92×10^{12} t per year). The ruminants' productivity is related to the supply of good quality fodder. On an average, only 4% of the sown area is under cultivable fodder production and the grazing land is only 3.5% of the total geographical area. Of the total fodder requirement in India, 57% is met from the forests. One of the aims of agroforestry systems is to optimize interaction between biological components like trees/shrubs and animals/crops for sustainability where MPTs play an important role. Datta and Singh (2007) reported suitable MPTs in subtropical humid climate in India. In India, the prominent role expected of MPTs is related to fodder and fuel. It is well known that lack of proper nutrition due to scarcity of feeds and fodders is one of the major constraints in ruminants' productivity. Fodder tree and shrub leaves make an important component of ruminant rations particularly in the hilly areas of India including north eastern region (Saha et al. 1997; Singh 1999; Sharma et al. 2000; Khatta et al. 2000) and can provide green fodder almost throughout the year. Tree leaves have sev-

Received: 2007-11-01; Accepted: 2007-12-14

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The online version is available at <http://www.springerlink.com>

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Responsible editor: Zhu Hong

eral advantages over the conventional cultivated fodder crops. They can produce green fodder per unit area comparable to cultivated crops; can withstand severe adverse climatic conditions; don not need heavy inputs (fertilizers, irrigation, labour, pesticides etc.); help in soil moisture conservation and also protect the environment. Feeding of selected tree leaves is a traditional practice in hilly areas. Therefore, determination of nutritional quality of these fodder sources is an important aspect of ruminant feeding and a step towards making balanced rations. However, there is scanty information on their nutritive value. Hence, the present investigation was undertaken to determine the nutritional quality of leaves of trees and shrubs grown in the arboretum.

Materials and methods

Leaves of 12 species of MPTs comprising of six species each the leguminous (*Acacia auriculiformis* Griesb., *Albizia procera* (Linn.) Benth., *Dalbergia sissoo* Roxb. ex DC, *Gliricidia maculata* HBK, *Leucaena leucocephala* (Lamk.) de Wit. and *Samanea saman* (Jacq.) Merrill) and the non- leguminous (*Azadirachta indica* A. Juss., *Eucalyptus hybrida*, *Gmelina arborea* Roxb., *Michelia champaca* Linn., *Morus alba* Poir. and *Tectona grandis* Linn. F.) were collected, dried in the hot air oven at 65°C for 24 hours and ground to pass through 1-mm sieve. These were analyzed for proximate principles (AOAC 1995), viz., dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE), nitrogen free extract (NFE) and total ash (TA) and cell wall constituents (Goering et al. 1970) viz., neutral detergent fibre (NDF), acid detergent fibre (ADF), hemi cellulose (HC), cellulose and acid detergent lignin (ADL). Total tannins (TT) were also estimated (Sastry et al. 1999). For mineral analysis, the samples were digested using di-acid mixture (HNO₃ + HClO₄). Calcium was determined using flame photometer (Systronics: Flame Photometer–130), phosphorus by colorimetric method (AOAC 1995) with double beam UV-VIS spectrophotometer

(Chemito, SPECTRASCAN UV 2600 PC) and trace minerals (Fe, Cu, Zn, Mn and Co) using Atomic Absorption Spectrophotometer (GBC 932 plus). *In vitro* dry matter and organic matter digestibility (IVDMD and IVOMD) was determined as per Tilley and Terry (1963) using a two stage technique.

For determination of gas production, incubations were done using *in vitro* system at 39°C under anaerobic conditions and gas production was measured at 0, 2, 4, 6, 8, 12 and 24 h. Metabolisable energy was determined (Menke et al. 1979) using gas production and chemical analysis (CP and EE) data. All the determinations were carried out in triplicate. Strained rumen liquor was used as inoculum for *in vitro* digestibility and gas production studies. Three rumen fistulated crossbred adult male cattle (BW=(332.6±18.6) kg) fed according to their requirements (NRC 2001) were used as donor animals for rumen liquor. Data were analysed using completely randomized block design and various correlations were drawn (Snedecor et al. 1989).

Results

Proximate composition

Data on proximate composition of the leaves of 12 species of MPTs including six species each of leguminous and non-leguminous grown in the agroforestry arboretum are presented in Table 1. There were significant ($P<0.01$) variations among the tree species with regard to proximate composition. The DM content averaged (36.51±1.12)% ranging from 27.78% to 46.12%. The CP concentration ranged from 10.06% (*G. arborea*) to 23.33% (*L. leucocephala*) with an average of (16.00±0.74)%. The CF value varied from 9.19% (*E. hybrida*) to 29.41% (*A. procera*) with an overall mean of (18.97±1.07)%. The average NFE level was observed to be (54.00±1.12)%. Total ash contents ranged from 5.74% (*A. procera*) to 11.45 % (*M. alba*) averaging (7.98±0.30)%.

Table 1. Proximate composition of MPTs in the agroforestry system

MPTs	Family	On DM basis (%)**						
		Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	Nitrogen free extract	Total ash
<i>Acacia auriculiformis</i>	Mimosaceae	34.10	93.57	13.10	3.29	25.23	51.95	6.43
<i>Albizia procera</i>	Mimosaceae	43.14	94.26	19.00	3.58	29.41	42.27	5.74
<i>Azadirachta indica</i>	Meliaceae	31.06	91.56	17.04	2.74	11.52	60.26	8.44
<i>Dalbergia sissoo</i>	Fabaceae	43.09	90.90	13.09	3.35	20.67	53.81	9.08
<i>Eucalyptus hybrida</i>	Myrtaceae	33.26	92.63	10.45	4.39	9.19	68.60	7.37
<i>Gliricidia maculata</i>	Fabaceae	29.21	92.90	21.66	4.04	16.92	50.28	7.10
<i>Gmelina arborea</i>	Verbenaceae	41.04	92.57	10.06	1.98	22.42	58.12	7.43
<i>Leucaena leucocephala</i>	Mimosaceae	32.23	93.85	23.33	1.92	12.83	55.77	6.15
<i>Michelia champaca</i>	Magloniaceae	46.34	90.52	16.84	3.02	17.36	53.30	9.48
<i>Morus alba</i>	Moraceae	27.78	88.55	17.49	2.61	12.41	56.04	11.45
<i>Samanea saman</i>	Mimosaceae	46.12	91.16	19.62	2.72	24.24	44.58	8.84
<i>Tectona grandis</i>	Verbenaceae	30.70	91.74	10.33	2.92	25.49	53.00	8.26
Mean ±SE		36.51±1.12	92.02±0.30	16.00±0.74	3.05±0.13	18.97±1.07	54.00±1.12	7.98±0.30
Critical difference value		1.20	1.79	1.17	0.56	1.38	1.40	1.80

Note: ** $P<0.01$.

Cell wall composition and total tannins

The mean values for NDF, ADF, hemicellulose, cellulose and ADL were found to be (52.48±1.05)%, (31.72±0.97)%, (20.76±0.88)%, (16.97±0.70)% and (9.57±0.62)%, respectively (Table 2). There were significant ($P<0.01$) differences among MPTs for cell wall constituents. *T. grandis* possessed the highest (67.94%) NDF level while *L. leucocephala* had the lowest (44.63%). The lowest (19.13%) content of ADF was also recorded in *L. leucocephala* and the highest (38.80%) in *D. sissoo*. Hemi cellulose content ranged from as low as 14.05% (*G. arborea*) to as high as 29.90% (*T. grandis*). The highest (23.76%) value for cellulose was recorded in *S. saman* and the lowest (12.02%) in *M. alba*. A large variation (3.90% to 18.20%) was observed for

ADL level. The contents of total tannins ranged from 1.50% (*M. alba*) to 6.86% (*A. auriculiformis*) with an average of (4.22±0.32)%. Tree species differed significantly ($P<0.01$) for total tannins values (Table 2).

In vitro DM and OM digestibility and metabolisable energy

The IVDMD and IVOMD values (Table 2) averaged (48.96±1.30)% and (50.69±1.36)%, respectively. The highest values for IVDMD and IVOMD were recorded in *L. leucocephala* (65.20% and 67.66%) and the lowest (37.90% and 39.36%) in *T. grandis*. The ME values ranged from 5.79 (*M. champaca*) to 7.95 MJ·kg⁻¹ of DM (*L. leucocephala*) averaging (6.95±1.11) MJ·kg⁻¹ DM, (Table 2).

Table 2. Cell wall composition, *in vitro* digestibility, metabolisable energy and total tannin contents of MPTs

MPTs	Cell wall constituents** (%)					In vitro digestibility** (%)		ME** (MJ·kg ⁻¹)	TT** (%)
	Neutral deter- gent fibre	Acid deter- gent fibre	Hemi cellulose	Cellulose	Acid deter- gent lignin	Dry matter	organic matter		
<i>A.auriculiformis</i>	55.36	34.44	20.92	17.40	12.54	38.92	40.65	6.53	6.86
<i>A. procera</i>	54.08	38.69	15.59	14.22	18.20	47.15	49.35	6.26	4.06
<i>A. indica</i>	48.85	28.52	20.33	17.52	6.83	54.40	55.82	7.25	2.80
<i>D. sissoo</i>	53.88	38.80	15.08	23.37	8.98	55.78	57.30	7.40	6.55
<i>E. hybrida</i>	49.16	31.00	18.16	18.43	7.94	42.53	44.52	6.30	3.04
<i>G. maculata</i>	51.38	25.33	26.05	12.19	10.92	52.16	54.08	7.56	3.10
<i>G. arborea</i>	44.55	30.50	14.05	14.16	11.86	41.80	42.13	6.97	4.99
<i>L. leucocephala</i>	44.63	19.13	25.50	12.38	3.90	65.20	67.66	7.95	2.82
<i>M. champaca</i>	57.64	29.10	28.54	15.74	9.32	46.37	48.50	5.79	5.89
<i>M. alba</i>	48.18	30.86	17.32	12.02	4.80	54.36	56.14	7.56	1.50
<i>S. saman</i>	54.16	36.28	17.88	23.76	8.15	51.05	52.72	7.03	2.20
<i>T. grandis</i>	67.94	38.04	29.90	22.45	11.44	37.90	39.36	6.76	6.79
Mean ± SE	52.48 ±1.05	31.72 ±0.97	20.76 ±0.88	16.97 ±0.70	9.57 ±0.62	48.96 ±1.30	50.69 ±1.36	6.95 ±0.11	4.22 ±0.32
CD value	1.43	1.48	1.01	0.94	0.47	2.26	2.06	0.37	0.34

Note: ** $P<0.01$

Macro and trace minerals

The level of Ca and P was found to be (1.22±0.07) (0.65% – 1.89%) and (0.21±0.01) (0.10-0.29%). *D. sissoo* contained the highest Ca concentration (1.89%) followed by *L. leucocephala* (1.79%). *L. leucocephala* also had the high P concentration (0.29%). Overall ratio of Ca to P was 5.80:1, which is quite wider compared to normal ratio of 2 to 1 and ratio of 4 to 1. The mean concentration of (153.49±12.36)(57.65-284.70), (7.04±0.61) (2.63-14.85), (72.47±11.76) (5.56-244.29), (199.53±35.19) (29.46-661.11) and (0.19±0.02) (0.05-0.35) mg·kg⁻¹ DM were recorded for Fe, Cu, Zn, Mn and Co, respectively (Table 3).

Correlations

Correlations (r values) among different parameters are presented in Table 4. The CP level in the leaves had a significant ($P<0.05$) positive correlation with IVDMD (0.72), IVOMD (0.72) and ME

(0.27) values. On the other hand, CF, NDF, ADF, ADL and total tannins showed significantly ($P<0.05$ or $P<0.001$) negative correlation with these 3 parameters. ME had positive correlation with *in vitro* digestibility.

Discussion

The values obtained for proximate principles in this study were in the normal range (Varma et al. 1982; Singh 1982; Bhatia 1983; Kundu et al. 1988; Valli et al. 1998; Parthasarthy et al. 1998; Chander Datt, 2005, Chander Datt et al. 2007). In general, leguminous trees had higher CP content than the non-leguminous ones, which is in agreement with other studies (Valli et al. 1998; Parthasarthy et al. 1998; Chander Datt et al. 2007). All the MPTs possessed more than 10% of CP. Below this level, rumen fermentation is adversely affected (Alam et al. 1994). Most of these species were rich in CP and the concentration was higher than grasses and most of cultivated fodders, however, their CF levels are comparatively low (Barbind et al. 1994; Saha et al. 1997;

Mandal 1997; Chander Datt et al. 2006).

There were significant differences in cell wall composition among MPTs. *A. procera* possessed exceptionally high level of lignin (18.20%). Cell wall constituents of these MPTs were comparable to those observed by other workers (Saha et al. 1987; Kundu et al. 1998; Valli et al. 1998; Khatta et al. 1999; Sharma et al. 2000; Chander Datt et al. 2007). The range of tannin con-

tents ((1.50–6.86)%) in the present study is comparable with others (Valli et al. 1998; Parthasarthy et al. 1998; Singh 1999; Khatta et al. 1999; Sharma et al. 2000; Chander Datt et al. 2007), however, variability in tannin content in tree leaves at different places is expected owing to several factors viz., geographical distribution of plant species, climate, maturity, etc.

Table 3. Mineral status of MPTs in agroforestry system

MPTs	Major* (%)		Trace** (mg·kg ⁻¹)				
	Ca	P	Fe	Cu	Zn	Mn	Co
Critical level***	< 0.30	< 0.25	< 50	< 8	< 30	< 40	< 0.1
<i>A. auriculiformis</i>	1.23	0.27	120.95	5.66	110.24	69.08	0.09
<i>A. procera</i>	1.47	0.19	133.05	3.16	5.56	29.46	0.26
<i>A. indica</i>	1.10	0.25	235.13	8.22	45.64	110.96	0.16
<i>D. sissoo</i>	1.89	0.20	57.65	10.12	15.81	175.45	0.17
<i>E. hybrida</i>	0.95	0.10	69.92	4.40	33.73	661.11	0.13
<i>G. maculata</i>	1.59	0.24	119.86	4.10	11.98	48.18	0.28
<i>G. arborea</i>	0.93	0.18	216.86	14.85	157.08	182.10	0.12
<i>L. leucocephala</i>	1.79	0.29	244.29	12.96	244.29	161.32	0.35
<i>M. champaca</i>	0.65	0.22	62.91	7.54	44.50	635.30	0.06
<i>M. alba</i>	1.38	0.24	284.70	5.88	96.07	90.98	0.28
<i>S. saman</i>	1.03	0.14	128.10	2.63	6.50	45.26	0.31
<i>T. grandis</i>	0.68	0.17	168.10	5.30	98.30	195.12	0.05
Mean ± SE	1.22±0.07	0.21±0.01	153.49±12.36	7.04±0.61	72.47±11.76	199.53±35.19	0.19±0.02
CD value	0.19	0.04	7.01	0.04	8.10	6.71	0.04

Notes: *P<0.05, **P<0.01, ***Prabowo et al. (1990).

Table 4. Correlation (r values) among different parameters

Parameter	In vitro dry matter digestibility	In vitro organic matter digestibility	Metabolisable energy
CP	0.72**	0.72**	0.27
CF	-0.45**	-0.48**	-0.24
NDF	-0.51**	-0.50**	-0.51**
ADF	-0.50**	-0.51**	-0.39*
ADL	-0.61**	-0.64**	-0.45**
Total tannins	-0.54**	-0.56**	-0.35*
ME	0.59**	0.57**	1.0

Notes: *P<0.05, **P<0.01.

Under the conditions of such a high ratio of Ca to P (5.80: 1) observed in the study, it should be adjusted to normal one (2:1 to 4:1) by supplementation with P for their proper utilization in the animal system (McDowell 1992) when tree leaves make a significant part of the animal ration. Most of the MPTs were adequate to rich sources of Ca, Fe and Mn, however, about 75% were deficient in P, 67% in Ca, 58 % in Zn and 25% in Co (Chander Datt et al. 2004) when compared to critical levels (Prabowo et al. 1990). Therefore, these minerals should be supplemented in order to avoid production losses considering the essentiality of minerals (Chew 2000) for growth, health, reproduction, production as well as normal biological functions of animals. It was also noted that all the MPTs except *L. leucocephala* were deficient in one or the other mineral elements with the exception of Ca.

The digestibility values obtained in this study could corroborate well with the findings of others (Tewatia et al. 1991; Nag et al. 1992; Khatta et al. 1999; Sharma et al. 2000). About 50% of MPTs were found to have IVDMD/IVOMD values above 50 % and ME level of more than 7.00 MJ·kg⁻¹ DM, indicating their potential for use in ruminant rations.

The negative correlations of crude fibre and cell wall composition with in vitro digestibility and metabolisable energy are corroborated by others (Gurung et al. 1993; Dzowella et al. 1995; Khatta et al. 1999; Sharma et al. 2000; Adem et al. 2005). These negative effects could be due to the facts that lignin causes depression in digestibility by physical encrustation and chemical bonding with structural carbohydrates while polyphenols or tannins inhibit the activity of rumen microbial enzymes thus lowering down the fermentative rate which in turn causes a decline in digestibility and ME contents of feeds as reported by (McLeod 1974; Makkar et al. 1988; Martin et al. 1998). ME values had a significant (P<0.01) positive correlation with DM and OM digestibility. Based on IVDMD, IVOMD and ME values, *L. Leucocephala* seemed to be a very good fodder. However, caution should be observed for its use in cattle ration. Cattle can be safely fed *Leucaena* leaves up to a level of 30% (DM basis) but when it makes more than 50% of the diet for longer periods, the toxicity symptoms like loss of hair, excessive salivation, poor growth, swollen thyroid etc. may occur (National Academy of Sciences 1977). The ill effects are due to the presence of an anti-nutritional factor, mimosine, which is converted to dihydroxyypyridone, a goitrogen, in the rumen. The others like *G. maculata*, *D. sissoo*, *A. indica*, *S. Saman* and *M. alba* could be

categorized as medium type while the rest as poor quality feed-stuffs.

Conclusion

There were significant ($P<0.01$) variations among the different plant species with regard to proximate principles, cell wall constituents, total tannins, mineral status, IVDMD, IVOMD and ME values. Leguminous trees contained higher level of CP as compared to non-leguminous ones though most of these were rich. These MPTs were adequate to rich in Ca, Fe and Mn, however, many of them were deficient in P, Cu, Zn and Co and possessed a very wide ratio of Ca to P. About half of the tree species possessed IVDMD/IVOMD values above 50% and ME values greater than $7.0 \text{ MJ}\cdot\text{kg}^{-1} \text{ DM}$. Crude protein content had significant ($P<0.01$) positive correlation with IVDMD, IVOMD and ME values while NDF, ADF, hemi cellulose, lignin and total tannins were negatively correlated with these three parameters. Based on the results, leaves of *L. leucocephala*, could be considered of good quality, and those of *G. maculata*, *M. alba*, *A. indica*, *D. sissoo* and *S. saman* medium type and others poor quality. Therefore, selected tree species should be propagated in different agroforestry systems so that they could be used as supplements to low quality fodder and straw based diets in ruminants for their better utilization.

Acknowledgements

The authors are grateful to the Director, ICAR Research for NEH Region, Umiam-793103, Meghalaya, India for providing the necessary facilities to carry out this research work. The support provided by Dr.(Mrs.) A. Chhabra, Principal Scientist, Dairy Cattle Nutrition Division, National Dairy research Institute, Karnal-132001, Haryana, India in carrying out in vitro rumen studies is also duly acknowledged.

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